

# Development of Biodiesel from Castor Oil

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**Abstract**-This paper represents method of producing biodiesel from castor oil (treated with mineral turpentine oil) by transesterification of the crude oil with methanol in the presence of NaOH as catalyst. This paper mainly involves "Esterification". Factors effecting the biodiesel production (reaction temperature, reaction rate & catalyst) are analyzed. The esterification procedure converts castor oil to its methyl esters. Important fuel properties of methyl esters of biodiesel produced from castor oil like viscosity, flash point, fire point, calorific value etc., was found out and compared to the properties of Indian standard biodiesel. This paper study supports the production of biodiesel from castor oil as a viable alternative to the diesel fuel.

**Keywords**-Renewable; Castor oil; Biodiesel

## I. INTRODUCTION

Petroleum based fuels are fuels stored in earth. There are limited reserves of these stored fuels & they are not renewable. With increasing power consumption and an increase in number of transport vehicles the coal pits are going to empty within short period. The world at present heavily depends upon petroleum fuels for transportation and for operating agriculture machinery. Diesel engines dominate the field of transportation and agriculture machinery on account of its superior fuel efficiency. The consumption of diesel in India is several times higher than that of petrol consumption. Roughly estimate of petrol and diesel consumption is 30% and 70%, respectively. Reserves appear to grow arithmetically while consumption is growing geometrically. Under this situation world will be leading to an industrial disaster.

The diesel engine is a major contributor to air pollution especially within cities and along urban traffic routes. In addition to air pollution that causes ground level ozone and smog in the atmosphere, diesel exhaust also contains particulate and hydrocarbon toxic air contaminants (TAC). Now society has become more aware of harmful effects of the various exhaust emission coming out of the engines and there is tremendous pressure on researchers to reduce exhaust emissions. Various harmful effects of exhaust emission are already established and known to today's society. Carbon monoxide, if inhaled, enters the blood stream and causes hypoxia, which leads to further health problems. Hydrocarbon emissions are irritant and odorants and some of them carcinogenic. Oxides of nitrogen are found to be responsible for many of the pulmonary diseases.

## II. POTENTIAL OF VEGETABLE OIL AS FUELS FOR I.C. ENGINES

### A. Suitability of Vegetable Oil as Diesel Engine Fuel

Biomass derived oils are quite promising alternative fuels for diesel engines. Concept of using vegetable oil as fuel dates back to 1885, when Dr. Rudolf Diesel developed first diesel engine to run on vegetable oil. There are more than 350 oil bearing crops identified whose cetane number and calorific value are comparable with those of diesel fuels and are compatible with material vehicle fuel system. Vegetable oil is of special interest because it has shown to significantly reduce particulate emission relative to petroleum diesel. Recent studies indicate that cetane number, aromatic content and type, sulphur content, density etc. of fuel are important factors for emission control. Different oil producing crop and their yield per acre land is shown in table no. 1.

Table 1. DIFFERENT EDIBLE & NON EDIBLE OIL PRODUCING CROPS AND THEIR YIELD

Oil Producing Crop /Plant	Yield (Lb Oil/Acre)
Palm	4585
Coconut	2072
Sunflower	734
Soybean	344
Cottonseed	250
Jatropha	1458
Castor bean	1089
Rubber seed	199

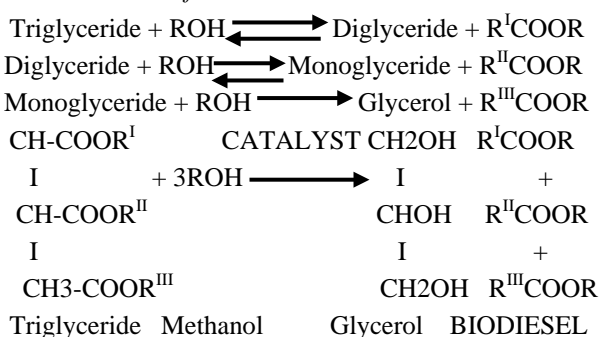
### B. High Free Fatty Acid (FFA) Systems

High free fatty acid will result in formation of soap or saponification in base catalyzed system. The maximum amount of free fatty acids allowed in a system can be 2%, preferably less than 1%. In case the oil has a high FFA content then there needs to be neutralization reaction with a base, NaOH. This reaction, carried with an indicator, is used to neutralize the excess acid present in the oil with the help of the base. Example of oil that can contain a significant quantity of FFA is waste vegetable oil (WVO). Sometimes this caustic is also added to the WVO directly and a process called caustic stripping is utilized. In this process, the resulting soaps are separated with the help of a centrifuge where in the high centrifugal forces can lead to separation.

### C. Need for Transesterification

Use of vegetable oils in diesel engines leads to slightly inferior performance and higher smoke emissions due to their higher viscosity and carbon residue. Filter plugging and cold starting along with higher specific consumption are observed while using vegetable oil due to their higher viscosity and lower calorific value. The performance of vegetable oil can be improved by modifying vegetable oil by transesterification process. The process of converting the raw vegetable oil using methanol/ethanol in presence of catalyst like NaOH into biodiesel, which is fatty acid alkyl ester is termed as transesterification. The reaction is as follows:

#### D. Transesterification Process



Where RI, RII, & RIII are long chain hydrocarbons

Table2. IMPORTANT FUEL PROPERTIES

Properties	Unit	Diesel	Castor oil	Castor oil ester	Castor oil ester treated with mineral turpentine oil.	Standard Value BIS:15607
Density(15°C)	kg/m <sup>3</sup>	880	950	925	878	860 - 900
Flash point	°C	47	230	200	125	120 MIN
Kinematic Viscosity (40 °C)	mm <sup>2</sup> /s	2.27	240	24	5.5	2.5-6.0
Cetane No.	-----	47	40	42	48	45 MIN
Net calorific Value	(MJ/Kg)	42.5	37	37.5	39.5	40
Iodine Value	-----	-----	100	90	80	120 MAX

Biodiesel refers to any diesel equivalent ester based oxygenated biofuel produced by transesterification process from renewable biological material such as vegetable oil (Edible & Non edible). Chemically biodiesel is known as "Free Fatty Acid Methyl Ester". A number of researchers have shown biodiesel has fuel properties and provides similar engine performance as that of diesel fuel. It is nontoxic, biodegradable, renewable fuel. Further advantages of

biodiesel over petroleum based diesel fuel include a higher cetane number, lower sulphur, lower aromatics, lower volatility and presence of oxygen atom in the molecule. The use of biodiesel in conventional diesel engines results in substantial reduction of unburnt HC & CO. Researchers have concluded Biodiesel is clean fuel, since it has almost no sulphur, no aromatics and has 10% built in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in petroleum diesel. First successful trial run on a superfast passenger train was conducted on December 31, 2002 by Indian Railway on Delhi-Amritsar Shatabdi Express with use of 5% biodiesel, which helped Railways in Fuel bill reduction.

#### E. Procedure for Production of Biodiesel

Raw materials required:

- Used or fresh vegetable oil (strained with a coffee filter or cloth)
- Lye (Catalyst)
- Methanol
- Isopropyl Alcohol (for tests. Use 99% IPA)

##### 1) Titration Process to Determine Lye Quantity:

Free fatty acids will increase with the amount of time vegetable oil has been heated. Oil which has been used for cooking will require more of the reactive agents (lye and methanol) than fresh oil. The presence of too many free fatty acids will retard or stop the reaction which produces biodiesel, so it is necessary to detect the exact amount of LYE (Sodium Hydroxide or NaOH) needed to neutralize. Adding too much or too little NaOH will just make excessive amounts of by-products (soap).

##### 2) To Determine Reaction Proportion:

To find the total amount of NaOH to be added we add the number of drops of NaOH needed for the wasted vegetable oil solution to reach a pH of 8-9 and 3.5 grams NaOH to catalyze the oil (stoichiometric).

An example formula used with one particular batch of wasted vegetable oil: 1ml of oil was titrated with a 1gm NaOH/1000ml H<sub>2</sub>O solution. It required 6.0ml to raise the pH level to 8. Hence 6.0gm/1000ml to neutralize the free fatty acids + 3.5g NaOH as catalyst = 9.5g per 1000ml oil.

##### 3) Vegetable Oil:

Diesel has a chain of 11-13 carbons and new vegetable oil has a chain of about 18, but waste vegetable oil, which has been heated, has chain of up to 32 carbons. To burn in an engine the chain needs to be broken down to be similar in length to diesel.

##### 4) Lye (Catalyst):

Lye is the catalyst used for transesterification. It works by "cracking" the vegetable oil molecules, splitting the triglycerides from the hydrocarbons and shortening the carbon chain of 3.5gm or 0.35% is the standard amount of lye necessary to create a reaction, when using fresh vegetable oil. Due to the presence of a very small quantity of FFA we add an

additional 0.3 to 0.4 grams in order to neutralize completely.

#### 5) Methanol:

The amount of methanol needed will also vary, but the ideal is to use the least amount of methanol necessary in order to get the highest yield. The yield is related to completion so if you get 90% yield that means that 90% of the fatty acids have been eliminated from the vegetable oil. We have found that the best is to use 15% to 20% methanol, based upon the total weight of batch of oil.

A hydrometer can also be used to check the amount of completion according to density.

### III. ESTERIFICATION SETUP

#### A. Main Reactor

The first aspect with respect to the design of the reactor was the total volume of the reactor. As was decided that a maximum output of 8 liters of bio-diesel was required from a single batch, the total required volume of the reactor was estimated to 10 liters. This volume is required to accommodate all the reactants *vis versa* vegetable oils, methanol and the lye in the recommended ratios.

Hence with the required volume in consideration a cylindrical shape was sought to be appropriate. Since it was decided that the flow of liquid contents from one vessel to the other would be assisted by gravity, use of a tapered conical section at the bottom of the viscous fluid. Glycerol is highly viscous and the formation of this would result in sluggish flow of the reacted mixture from the reactor.



Fig. 1

The system requires to be closed system and hence a flange was designed to prevent any leakage of the methanol which could vaporize due to heating and potentially be health hazard. Hence the whole system was designed to be air tight with the use of a flange and a rubber bush to prevent any leakage. Since it was observed that methanol has tendency to vaporize and to allay a fear of explosion due to increase in pressures, use of pressure relief valve (PRV) was envisaged.

As the reaction requires vigorous stirring and heating, the design was involved to integrate the stirring and the heating systems into the main reactor. The main reactor was designed to include baffles to provide for higher mixing sufficiency and more uniform temperature during the reactions.

#### B. Separating and Washing Vessels

From the literature study and the preliminary laboratory experiment it was observed that immediately after the reaction period, i.e. the length of time for which the reaction occurs and during which both stirring and heating of time for which the reaction mixture should be allowed to cool and settle. The settling period allows for the reaction mixture to separate into the two products namely glycerol and the biodiesel. The separation occurs over a period of about 6 or more hours.



Fig. 2

It was decided to separate the reaction contents from the main reactor into two separate vessels to facilitate washing of the bio-fuel. Once the reaction contents are transferred the two settling vessels, they are allowed to separate. To enable viewing of the settling between the lower glycerol layer and the upper bio-fuel layer, a glass tube was designed to be accommodated into the separating vessel and in turn facilitates easier removal of the glycerol from the bio-fuel.

The separating vessels are designed to be cylindrical in shape with a capacity to accommodate more than 10 liters to hold water necessary for bubble washing. The quantity of water is estimated in the ratio of 2:1 i.e. for every one part of bio fuel two parts if warm water is required.

The biofuel separated in this stage still impure and needs to be cleansed in a process known as bubble washing. This process involves cleaning the fuel with water by using agitation which is provided by pumping air through the water and biodiesel mixture.

The washing system was designed using a pump to deliver air through a pipe to a diffuser inside the washing/separating vessel. The diffuser used for this purpose is to be integrated into the tank with the help of the appropriate piping from the pump.

The design involves the pump to be positioned at a height greater than the position of the diffuser in the tank. This is necessary to prevent reverse flow of fluid from the tank into the pipe providing the compressed air. A one way check valve is also provided at the diffuser attachment in the tank to prevent flow of liquid into the Same Pipe.

### IV. PRODUCING BIODIESEL FROM CASTOR OIL

India is having great demand of edible oil for cooking purpose & it is expensive too. The main source of biodiesel in India can be nonedible oil. So castor oil can be considered to manufacture biodiesel. *Ricinus communis* is a species that belongs to the Euphorbiaceae family known as castor oil plant [3]. This plant is easy to grow & is resistant to drought. Castor oil is best substance for producing biodiesel because it is the only one that is soluble in alcohol & does not require heat & consequent energy requirement of other vegetable oils in transforming them in to fuel. Castor oil is one of hard oil where oil content in the seed is high, i.e. 50% of total by weight –the castor bean contains 50-55% oil. As viscosity of castor oil is 100 times more than diesel, it can not be injected, atomized & combusted properly in its original form so it is necessary to reduce its viscosity to make it suitable for C.I.Engine application by Transesterification process.

#### *Procedure for Preparation of Biodiesel From Castor Oil*

Castor oil is to be collected for further processing as bio diesel. The methodology developed / processes adopted for production of bio-diesel is given below. Whole process is described for one liter of castor oil. During processing of multiple quantity of castor oil, chemical constituents should be changed in the same proportion however timing for heating, settling and washing remain same.

- One liter of castor oil is to be taken.
- 300-330 ml of methanol & 10 ml of concentrated sulphuric acid is to be added to oil.
- The temperature of this mixture is to be set at 65-70 °C.
- This temperature of the mixture is to be maintained for about 6 hours and stirred continuously.
- The mixture is to be allowed to settle for 8 hours after completion of this reaction. This settled reactant mixture would consist of two layers.
  - a. Upper layer as bio diesel and traces of glycerin etc.
  - b. Bottom layer as glycerin and gums etc
- The glycerin is to be removed from the Bio-diesel preparation unit by opening the tap provided on the bottom.
- This pre washed bio diesel is taken in a separating funnel.
- 200 ml of hot water at approximately 40° C is added per liter of crude biodiesel and shaken well & allowed to settle to separate two layers for nearly 7-8 hours.
- Above process is repeated at least three times so that the traces of glycerin and soap get removed & the bio diesel produced from castor oil is ready for use.
- For adjusting viscosity esterified castor oil was further treated with mineral turpentine oil(M.T.O.).

#### V. FUEL CHARACTERIZATION:

The fuel prepared was tested in laboratory and results obtained are summarized in table no. 2.

##### A. Density

It is the mass per unit volume. Oils that are denser contain more energy. Castor oil has density 950 kg/m<sup>3</sup> (At 15° C). & after esterification it reduces to 925 kg/m<sup>3</sup> & after treatment of esterified castor oil with mineral turpentine oil (M.T.O.) it further reduced to 878 kg/m<sup>3</sup>. This value is comparable with density of diesel which is 880 kg/m<sup>3</sup>.

##### B. Flash Point

It is the minimum temperature at which fuel will ignite (flash) on application of ignition source. It varies inversely with fuel's volatility. Castor Oil has its value 230 ° C & After esterification it is 200 ° C & After treatment of esterified castor oil with Mineral Turpentine Oil it is 125 ° C which is higher than that of diesel (47 ° C) and so why safe to store.



Fig3. Castor oil



Fig4. Biodiesel

##### C. Kinematic Viscosity

It refers to the thickness of oil & is determined by measuring amount of time taken for a given measure of oil to pass through an orifice of a specified size. It affects injector lubrication & fuel atomization. Fuels with lower viscosity may not provide sufficient lubrication for injection pump resulting in wear & high viscosity tends to form larger droplet which can cause poor combustion & increased exhaust smoke & emission. Castor oil has viscosity 100 times more than that of diesel. Its value is 240 mm<sup>2</sup>/s (at 40° C). & after esterification it is 24 mm<sup>2</sup>/s & after treatment with Mineral Turpentine Oil it is 5.5 mm<sup>2</sup>/s. This value is comparable with kinematic viscosity of diesel which is 2.27 mm<sup>2</sup>/s. So castor oil ester treated with mineral turpentine oil will have better injection characteristics.

#### D. Cetane No

It is relative measure of interval between beginning of injection & auto-ignition of fuel. Higher no. gives shorter delay interval & greater combustibility & lower no. will result in difficult starting, noise & exhaust smoke. Its value for castor oil is 40 & after esterification it is 42 & after treatment with M.T.O. it is 48 which is higher than that of diesel which is 47. Increased cetane no. of castor oil ester treated with M.T.O. will result into better combustion.

#### E. Net Calorific Value

It is the amount of heating energy released by combustion of a unit value of fuel. Its value for castor oil is 37 MJ/Kg & after esterification it was 37.5 MJ/Kg & after treatment with M.T.O. it was 39.5 MJ/Kg. As compared to diesel having net C.V. 42.5 MJ/kg it is lower, so more fuel will be consumed to produce same power when castor oil ester treated with M.T.O. is used.

#### F. Iodine Value

It is amount of Iodine measured in grams, absorbed by 100 grams of given Oil. It is used as measure of chemical stability properties of biodiesel against oxidation. Its value for castor oil is 100 & after esterification it is 90 & after treatment with M.T.O. it is 80. This property is not that important for diesel fuel.

### VI. BIODIESEL PRODUCERS IN INDIA

Naturol bioenergy limited.

Reliance life sciences.

Southern online biotechnologies limited.

Gomti biotech ltd.

Royal energy limited.

Chemical biotech limited.

Coastal energy limited

### VII. ADVANTAGES OF BIO-DIESEL

There are numerous advantages of bio-diesels. Some of the most important are listed:

- Biodiesel runs in any conventional, unmodified diesel engine. No engine modifications are necessary to use

bio-diesel and there is no "engine conversion." In other words, "you just pour it into the fuel tank."

- Biodiesel can be stored anywhere that petroleum diesel fuel is stored. All diesel fuelling infrastructure including pumps, tanks and transport trucks can use bio-diesel without any major modifications.

- Biodiesel reduces carbon dioxide emissions, the primary cause of the greenhouse effect, by up to 100%. Since bio-diesel comes from plants and plants breathe carbon dioxide, there is no net gain in carbon dioxide from using bio-diesel.

- Biodiesel can be used alone or mixed in any amount with petroleum diesel fuel. A 20% blend of bio-diesel with diesel fuel is called "B20"; a 5% blend is called "B5" and so on.

- Biodiesel is more lubricating than diesel fuel, it increases the engine life and it can be used to replace sulfur, a lubricating agent that, when burned, produces sulfur dioxide. The primary component in acid rain. Instead of sulphur, all diesel fuel sold in France contains 5% bio-diesel.

- Biodiesel is safe to handle because it is biodegradable and non-toxic. According to the national bio-diesel board, "neat diesel is as biodegradable as sugar and less toxic than salt."

- Biodiesel is safe to transport. Bio-diesel has a high flash point, or ignition temperature, of about 150°C compared to petroleum diesel fuel, which has a flash point of 52°C.

- Engines running on bio-diesel run normally and have similar fuel mileage to engines running on diesel fuel. Auto ignition, fuel consumption, power output, and engine torque are relatively unaffected by biodiesel.

- Biodiesel has a pleasant aroma similar to popcorn popping in comparison to the all-too-familiar stench of petroleum diesel fuel.

### VIII. DISADVANTAGES OF BIODIESEL

The NO<sub>x</sub> emission is somewhat higher than the conventional diesel engines.

Since the biodiesel contains O<sub>2</sub> the specific fuel consumption would be higher than that of pure diesel oils.

### IX. CONCLUSION

Crude castor oil was transesterified using NaOH as catalyst and methanol to form biodiesel. The conversion was 92% at 600°C. The fuel properties like viscosity, density, flash point, fire point and calorific value of the transesterified product (biodiesel) compare well with accepted biodiesel standards i.e ASTM and Indian biodiesel standards. The viscosity of biodiesel oil is nearer to that of diesel and the calorific value is about 12% less than that of diesel. More lubricating than diesel, so it increases the life of engines, Biodegradable, Non toxic. High flash point and hence safe to transport and store, Oxygenated fuel and hence clean burning. Low viscosity and hence improved injection and atomization,

Ceatanes no. of esters is greater, Reduced emissions, 90% reduction in cancer risk, Provides domestic, renewable energy.

# REFERENCES

- [1] Y.C.Sharma ,B.Singh "Development of biodiesel from karanja , a tree found in rural India" Journal of Fuel, 1740–1742, 87 (2008).
- [2] Ganesan V. (2003), "Internal combustion Engines", Mcgraw Hill Publications, New Delhi.
- [3] Heywood J.B. (1998), "Internal combustion Engines Fundamentals", Mcgraw Hill, New York.
- [4] Sanjib Kumar Karmee,Anju Chadha "Preparation of biodiesel from crude oil pongamia pinnata"Journal of Bioresource Technology 96 (2005) 1425 -1429.
- [5] Vivek and A.K.Gupta "Biodiesel production from karanja oil" Journal of Scientific& Industrial Research, Vol 63 ,January 2004,pp 39-47.
- [6] L.C.Mehar ,S.N.Naik and L.M.Das "Methanolysis of Pongamia pinnata(karanja) oil for Production of biodiesel" Journal of Scientific& Industrial Research, Vol 63 ,November 2004,pp 913-918.
- [7] Sagar Pramodrao Kadu,Rajendra H.Sarda "Experimental Investigations on the use of Preheated neat karanja oil as fuel in a compression ignition engine" World academy of Science, Engineering and Technology, 72, 2010 pp 540-544.
- [8] P.K.Srivastava,Madhumita Verma " Methyl Ester of karanja oil as an alternate renewable source energy" Journal of Fuel, 1673–1677, 87 (2008).
- [9] Sudipta choudhury and Dr. P.K.Bose " Karanja oil-its potential and suitability as biodiesel.
- [10] H.Raheman,A.G.Phadatara " Diesel engine emissions and performance from blends of karanja methyl ester and diesel" Journal of Biomass & Bioenergy 27 (2004) 393-397.
- [11] K.Sureshkumar,R.Velraj,R.Ganesan "Performance and exhaust emission characteristics of a CI engine fueled with pongamia pinnata methyl ester (PPME) and its blends with diesel" Journal of Renewable Energy 33 (2008) 2294-2302.
- [12] G Lakshmi Narayana Rao, Sampath S, Rajagopal K. "Experimental Studies on the Combustion and Emission Characteristics of a Diesel Engine Fuelled with Used Cooking Oil Methyl Esterand its Diesel Blends." International Journal of Applied Science, Engineering and Technology,4 (2008).
- [13] G Lakshmi Narayana Rao ,Venkata Ramesh mamilla M.V.Mallikarjun'Performance and Emission Characteristics of CI Engine Fuelled with Jatropha Methyl Ester/Diesel Blends', International Journal of Mechanical & Automobile Engineering, Vol.05, No.7, 2010, pp.01-05.
- [14] G Lakshmi Narayana Rao, Sampath S, Rajagopal K. "Experimental Studies on the Combustion and Emission Characteristics of a Diesel Engine Fuelled with Used Cooking
- [15] Oil Methyl Ester and its Diesel Blends", International Journal of Applied Science, Engineering and Technology (IJASET), Vol.4, No. 2, 2007.
- [16] G Lakshmi Narayana Rao, Sampath S, Rajagopal K. "Combustion, Performance and Emission Analysis of Blends of Pungam (Pongamia Pinnata) Oil Methyl Ester and Diesel
- [17] on a Stationary DI Diesel Engine", communicated to Biomass and Bioenergy, Elsevier Science Ltd., UK.
- [18] G Lakshmi Narayana Rao, Sampath S, Rajagopal K. "Combustion and Emission Characteristics of Diesel Engine Fuelled with Methyl Esters of Pungam Oil and Rice Bran Oil", Accepted for publication, International Journal of Global Energy Issues, U.K.